STUDIES IN THE DRIFTLESS REGION OF WISCONSIN II.[1]

SINCE my article which appeared in the November-December number of the JOURNAL OF GEOLOGY was written, much additional evidence has accumulated, largely along new and supplementary lines. There have, however, been some additions along the lines there developed, which I beg to notice in an extended footnote.[2]

[1] On page 834 of my last article a change in the paragraphing somewhat obscured the course of the reasoning. The objections to torrential action were grouped under three heads: *a*, transverse ridges, beginning at the tenth line from the top; *b*, the lateral ridges; *c*, the size of the material.

The first head was improperly made to begin at the twenty-third line from the top, where there is only a reference to the ridge, *b*, Fig. 1. I think that I was myself partly the occasion of the mistake, since the *b* stood alone, Fig. 1 having been omitted. The third head should have been worded more in harmony with the others and more indicative of its own character.

[2] Regarding the ridge *d* (Fig. 1 of last article) I stated that it seems to belong structurally to both valleys. But the heavy masses of ferruginous sandstone which form so conspicuous a component of the ridge appear to be peculiar to the east valley. The knob *d* (Fig. 1) is composed of it. It also occurs on the north rim at *c* (Fig. 7). Although much harder than the sandstone in the same horizon on either side, it is not as prominent in the topography as we should have expected, owing probably to the fact that it has pronounced joint structure and the separate masses are rather easily dislodged. The supposed bowlder bed on the west side of the west valley (shown in gully) is of small material, undoubtedly a water deposit, leaving the ridge *b* (Fig. 1) as the terminal deposit for that valley.

An interesting feature has developed in connection with the ridge shown in Sec. 4, Fig. 2 of last article, occurring in the third valley described (position shown at *c*, Fig. 4). A well dug just in front of the line of the section struck at once into a clay resembling the loess and entirely free from stones. It continued in this for its entire depth, about twenty feet.

The terminal arrangements of the material in the last valley described (partly shown in Sec. 6, Fig. 2) displays a certain feature which claims further notice; an independence of the minor features of the topography, shown in the direction of movement and the disposition of the beds. In the accompanying figure I have represented by contour lines the original rock surface and by dots the contour of the lower end of the beds. The axis of the old valley runs very close under the eastern hill, while on the west a broad shelf rises gradually toward the nearest bluff.

Distribution of transported material on the higher slopes.—Most of the deposits previously described fall between the horizon of the present river-level and that of the highest terrace, so that although there seems to be excellent reason on other grounds

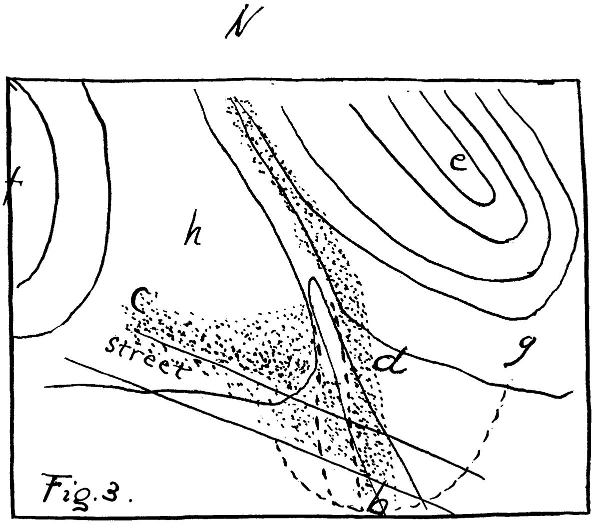

FIG. 3. Scale 300′ to an inch. Adapted from the village plat, which I used as the foundation.[1]

f. End of a short spur or projecting angle of one of the higher bluffs.

e. End of a long spur forming the northeast valley rim.

g, *h*. Rock shelves sloping gently from their adjacent hills.

ab. The bowlder ridge, the south end of which lies over the old rock valley, shown in entire lines, while the present drainage indicated by dotted lines runs further west just inside of the ridge. It has both an outward and an inward slope plainly apparent in spite of the loess, which, however, as the street cutting shows, greatly exaggerates its apparent breadth and diminishes its apparent height. The bowlder bed doubtless covers all of the shelf *h*, but being heavily covered with loess I have only indicated that part which is uncovered. On its south front it declines from a thickness of about twelve feet or fifteen feet to nothing in the width of a street.

The asymmetry of the deposits, *i. e.*, their presence on one side of a valley, and apparent absence on the other has been something of a difficulty in working out the

[1] These maps have necessarily been constructed without the aid of special measurements. But while they must needs lack the exactness which such a method would have given, they have been carefully constructed from fairly correct data, and after thorough study of the topography, and are essentially correct. The valley bottoms, however, offer especial difficulties, since the series of deposits of which the loess is the top, has been eroded so as to form a most intricate system of ravines of which only the principal ones could be represented.

for disputing the competency of running water, landslides or creep to give rise to such deposits, it cannot be denied that they lie within the horizon where such agents are operative. It is, therefore, very desirable to trace the deposits into higher levels. But the middle portions in all the valleys are so deeply covered by the loess — which has a strong tendency to fill up depressions and obliterate minor irregularities of surface — that nothing can be seen save in the rare cases in which gullies are deep enough to slightly expose the structure, and even these, although affording valuable evidence as to the sequence of the deposits, etc., give no decisive indication as to their character.

On the outlying secondary hills the loess is not so thick, and a systematic study of these has given unexpectedly interesting results. The accumulations there, unlike those of lower levels in which all the different local formations are represented, are composed almost exclusively of limestone from the tops of the

glacial hypothesis. But as shown above, while on one side the deposit may rest on a shelf, on the other it may lie in the axis of a valley, where if circumstances are favorable it may be covered by late deposits. This asymmetry is, however, quite as serious an objection to torrential action or to the flow of semiliquid material, neither of which could form deposits at a notably higher level on one side of a valley than on the other. At *c* the bowlder bed rises into a sharp ridge three or four feet high as shown in Sec 6, Fig. 2 (previous article). From *c* to *d* there is a nearly uniform eastward slope, broken only by the present drainage channel. Had there been nothing in the configuration of the ridge to confine the drainage it must have left the bowlder bed near *d*, to enter the lower level extending southeastward from thence. The dotted half circle drawn through points of approximately equal elevation on either side of the old drainage channel will show how widely the bowlder deposit departs from the normal plane of a water borne deposit.

There is an implied suggestion in Professor Chamberlin's note prefacing my first article, which requires more specific notice than I have yet given it. It is whether these deposits might not have resulted from landslides or from the lavalike flow of saturated earth during thaws, or the more gradual creep due to repeated thawing and freezing. Perhaps the best answer will be to state the conditions presented by a single case. The deposit shown in Sec. 3 (Fig. 2) of last article lies on a rock shelf and reaches to about forty feet above low water of the Mississippi, a height which is not reached in the valley for several hundred feet back. A 2° slope would not intersect the bottom of the valley at a distance much, if any, short of 1500 feet. To reach its present position from any possible source the material would have had to travel about 3000 feet and make a sharp bend in its course. Its probable source was one of the bluffs shown in Figs. 4 and 5, present article. Limestone is abundant in the deposit, and some of the fragments quite large.

higher bluffs. To this is added a comparatively small percentage of material from the transition beds at the base of the limestone.

Circs.— Short, direct valleys, with broad heads and narrow outlets, are finely shown in this vicinity. The deposits found in

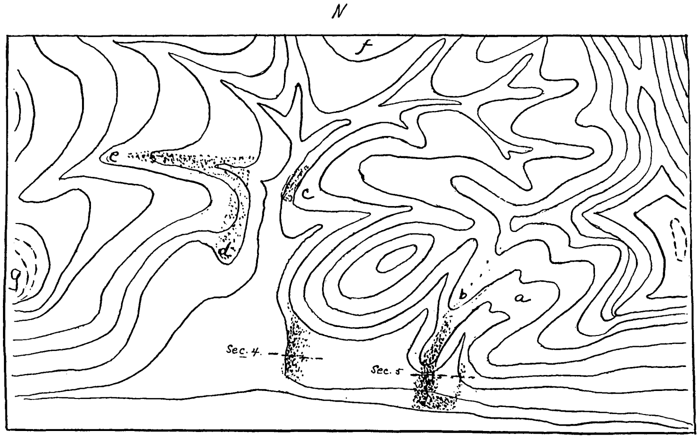

FIG. 4. Contour sketch map in which the center is occupied by the lower end of a large valley— the third in the series described. At the extreme right is a bluff, the highest and most massive in the group. Descending from this is the small valley or circ, *a*, the fourth described. The positions of Sects. 4 and 5 (Fig. 2) of the previous article are indicated. The bowlder deposits shown in Sec. 5 continue along up the crest of the ridge *b*, as shown by dots. I have endeavored by the greater or less concentration of the dots to indicate the relative abundance of the bowlder deposits. Sec. 4 (Fig. 2) was obtained at the point *c*. The peculiar point *d* appears to be largely or wholly composed of similar deposits. In the ravine, *e*, extensive washouts reveal very thick bowlder deposits. Doubtless similar deposits occur in the other ravines within the secondary hills, but the conditions are not favorable for observation. The lower end of the bowlder covered spur shown in Fig. 4 is seen at *f*. West of the middle of the valley, no hills reach the limestone horizon, save that at *g*. Scale 1000′ to an inch. Contour lines at intervals of 50′.

In this and the following maps I have indicated the base of the limestone horizon by heavier contour lines.

connection with them show several marked variations in detail from those found in the larger valleys, while they have a close resemblance among themselves. They all front on the Mississippi and are the result of the comparatively rapid erosion which its presence induces. The secondary hills which separate neigh-

boring circs are very wide at the outer margins, but narrow to ridges of only a few feet in width at the points where they join the primary bluffs. In some cases these connecting ridges have been so

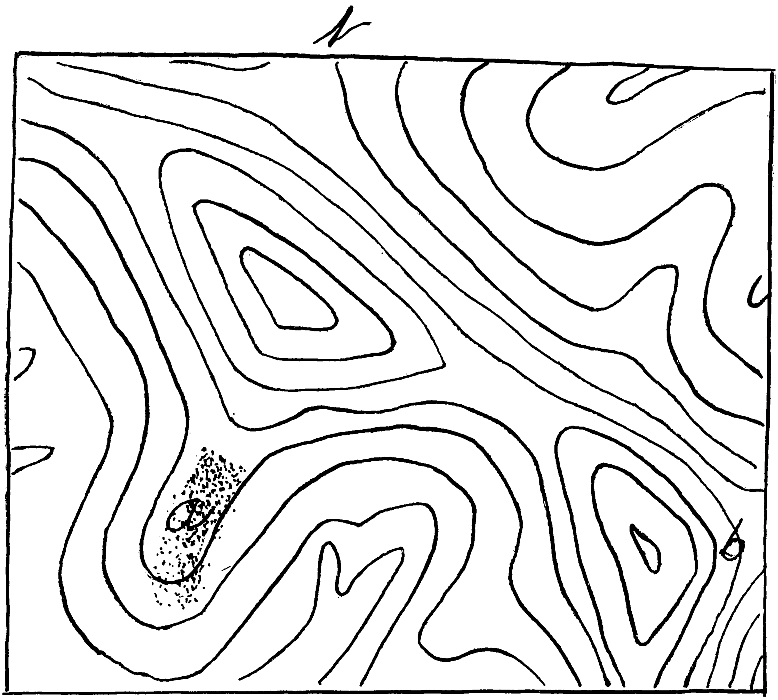

FIG. 5.—Sketch map of a portion of the same valley as shown in Fig. 4, joining that on the north—(east end). It shows a spur extending out from one of the angles of a limestone-covered bluff and having its top covered with limestone débris. It appears to extend downward somewhat on the east side, but, on account of the increasing thickness of the loess, it cannot be told how far. At *b* a spur of very similar height and form holds almost identical relations to its primary bluff, but it is entirely destitute of limestone débris. It is evident, therefore, that one has been subject to the action of some agent which did not effect the other. Scale 500′ to an inch. Contour lines at intervals of 50′.

worn away as to form a considerable sag. For convenience, I will speak of these secondary hills between circs as buttresses.

For the purpose of illustration I have selected one of the finest of these, which is shown in contour lines in the accom-

panying sketch map, Fig. 6, together with portions of the circs adjoining on either side. A portion of the main bluff, with its limestone cap, is shown in the upper right-hand corner (in order

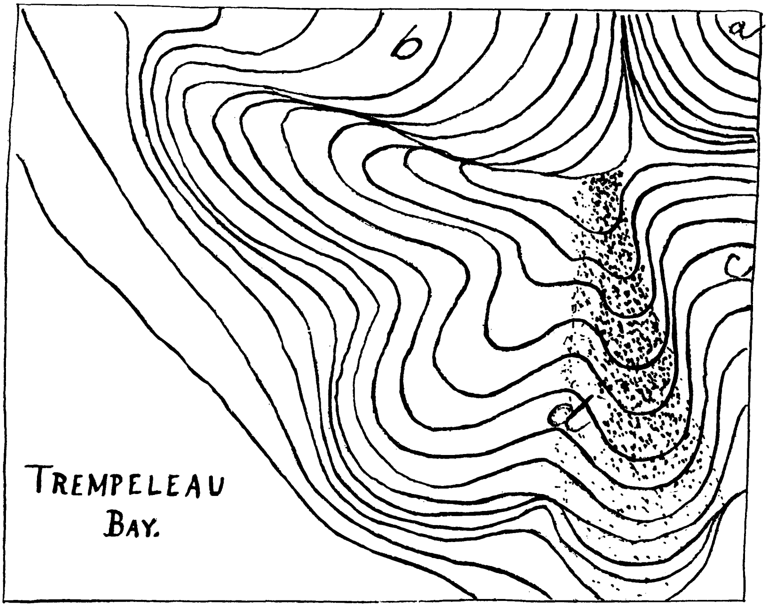

FIG. 6. Contour sketch map of a single buttress with a portion of its primary bluff, *a*, to illustrate the distribution of the limestone débris as shown in connection with the circs. Parts of two circs are shown, *b* and *c*.

The dotted portion shows where the limestone débris occurs. I have endeavored to show its relative abundance by the concentration of the dots. It should be observed, however, that while on the side furthest from the circ it is really represented by only scattered fragments, in the thickest part next the circ it is piled up to a thickness apparently of several feet. The side of the buttress toward the circ *c* is steep but not precipitous, but that toward *b* is a vertical escarpment several hundred feet long, and twenty to fifty feet high.

Scale 400′ to an inch. Contour lines at intervals of 25′.

to be more easily distinguished by the eye, the base of the limestone is represented by heavier contour lines). The dotted area on the east side of the buttress shows the portion covered by transported limestone. It is most abundant immediately adjoining a circ, diminishing as we recede from that, but not entirely

ceasing until we have passed the bottom of the nearest ravine (*d*, Fig. 6). When it occurs on both sides of a buttress, and there is but a single intermediate ravine, it extends in some degree over all parts. The maximum thickness of these accumu lations is nowhere shown in section. Such indications as I have noted lead me to the belief that it will probably not exceed six feet or seven feet, thinning off until it is represented by scattered bowlders only. There is often an appearance as though the material had been thrown into subordinate ridges of low relief. They are too faint, however, to be relied upon as evidence, unless their reality can be confirmed by sections. The fragments range from massive or tabular forms several feet across down through all grades, and they lie as close together as the fragments in a macadamized road. The slopes from the circs to the bounding buttresses are nearly always steep (35° to 40°). That overlooking the circ *b* (Fig. 6) is vertical for heights varying from twenty to fifty feet. The small valley shown at *a*, Fig. 4 has somewhat the character of a circ. The sharp ridge which forms its western rim, or buttress, has a train of limestone débris for the greater part of its length, sometimes rather straggling, but quite abundant on its knoblike outer end, and the terminal slope, at the bottom of which it connects with the ridge shown in Sec. 5, Fig. 2 (previous article).

The larger valleys.— Of the occurrences in the larger valleys two examples are here sketched. The first, Fig. 5, is found in the largest of the valleys (the third described in previous article). The highest portion of its rim lies toward the northeast (compare Fig. 4), and a portion of this, a peak of triangular form, is shown in the figure. The northwest-southwest portion is a part of the valley rim, while the spur, *a*, projects into the valley. The top of this spur is thickly covered with limestone débris, save the inner end, and the slope of the main bluff up to the base of the limestone, where it is lacking. Whether the deposit on the spur is continued eastward and southward into the valley cannot be told on account of the loess. The second example, shown in Fig. 7, occurs in the easternmost of the two

confluent valleys first described, in which the highest portion of the rim is toward the northwest, and consists of a high and rather long bluff, somewhat crescentic in form. The north rim of the valley consists of a much lower ridge, nowhere reaching

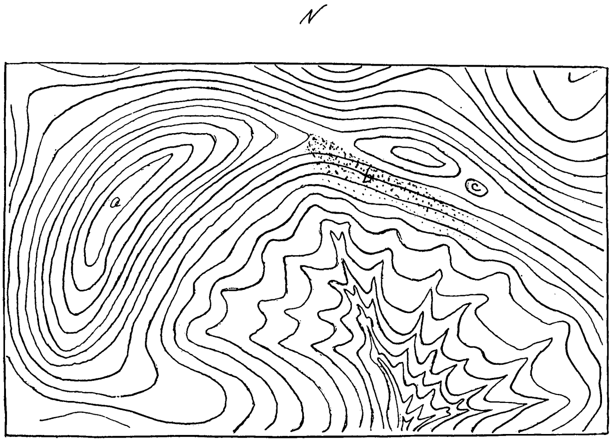

FIG. 7. Contour sketch map of the easternmost of the two confluent valleys first described in the last article. (The lower part is shown in Fig. 1.) The enclosing rim of the valley reaches the limestone horizon at only two points. One of these is the long bluff, *a*. The other would fall a couple of inches outside of the lower right-hand corner and is the same as the one shown at *g*, Fig. 4. At *b* occurs the train of limestone débris. Its downward extension is concealed by loess. *c*, knob of hard, ferruginous sandstone.

Scale 800′ to an inch. Contour lines at intervals of 25′.

to the horizon of the limestone. In proceeding eastward from the base of the limestone at the northeast end of the high bluff, limestone débris is lacking for some three or four hundred feet. It then appears suddenly on the top of the ridge, extending to an unascertained distance downward on the inside. A little further eastward the upper edge of the débris begins to fall a little short of the top of the ridge (on the inner side), and from that point it continues to decline at a nearly uniform rate, making an angle of about 4° or 5° with the horizon. The limestone is in sufficient abundance to wholly cover the ground up to almost the extreme limit of its occurrence, when within the space of a foot

or two it fails entirely. The figure does not exaggerate the nearly straight course followed by the upper margin of the deposit (to avoid misapprehension I may say that throughout the article, in speaking of limestone, only that derived from the Lower Magnesian horizon forming the caps of the higher bluffs is regarded, the limestone found at lower levels and belonging to the Potsdam series being carefully excluded).

I would call attention to the fact that all the examples given lie over against projecting angles of the primary bluffs. To reach the position occupied, material must have moved in defiance of the law which requires that it shall travel along the shortest available course from a higher to a lower level. We are obliged to account not for a few sporadic cases of such transportation merely, but for such an abundance as really amounts to a concentration. I therefore feel justified in saying that under existing conditions it is quite impossible that the material should have reached its present lodgment by rolling from the higher bluffs. In the case of the deposits on the buttresses, I have speculated as to the possibility of their having been earlier accumulations antedating the formation of the circs. But the hypothesis fails to explain all the facts even in these cases, and is of no assistance whatever in cases like those illustrated in Fig. 5 or Fig. 7.

The only tenable hypothesis remaining, as it seems to me, is that the valleys were filled with wind-drifted snow, which was piled up around the higher bluffs, so that only their limestone tops rose above. In such a case the limestone débris which reached the upper edge of the drifts would sooner or later work downward to a lodgment wherever the slope and other conditions were favorable. This involves the further assumption that the snow had been compacted to practically the consistency of glacier ice. So far as I have been able to bring it to a test, this hypothesis explains the various peculiarities remarkably well. All the localities showing limestone débris thus far discovered, are in places where, under the hypothesis, they would have been most likely to occur. Compare Fig. 5 and explanatory

notes. The minor features of distribution also harmonize well with it; for example, in Fig. 6, limestone is wanting on the north side of the buttress. But this side is remarkably high and the height is maintained for a long distance, and the upper surface of a drift having the average slope would have fallen much below the top of the perpendicular escarpment. Conversely there are other buttresses so small that a drift having the average slope would have buried them completely, and these also are destitute of the limestone.

It is evident that on this hypothesis the limestone accumulations furnish data from which we may calculate approximately some of the dimensions of the drifts. In some of the circs the slope may have been as high as 20° in places, but the average appears to have been nearer 15°. In the valleys it was much less, apparently ranging from 10° or 12° down to 4° or 5°. The greatest vertical thickness appears to have ranged between 200 and 250 feet in the valleys and between 80 and 120 feet in the circs

The hypothesis does not necessarily imply that the big drifts developed glacial motion, since the transit across their upper surfaces might have taken place though the drifts were themselves stationary. But if we may accept the existence of large bodies of snow in the valleys, as probable, the indices of glaciation shown in the lower portions of the same valleys gain greatly in importance.

The facts above given regarding the distribution of limestone on the bounding buttresses of circs, seems to render it desirable that some notice should be taken of their low level deposits. Unlike those connected with the larger valleys, these are almost wholly external, and have the form of alluvial cones. As seen in section, they display the concentric structure lines indicating the successive stages of their upbuilding. These are more pronounced on either side of the center where also the material is usually fine.

Along the center, or axis, bedding planes are often faint, or lacking, and much heavy material is included. As might be

expected, the coarse material is a fairly representative assemblage from the different horizons.

So far there is nothing to suggest glacial action. But two bowlders seen in the railroad cutting are noteworthy on account of their character, and certainly suggest some such agent. They are tabular forms six or seven feet across, and two to three feet thick, derived from the thin-bedded, impure limestones of the Potsdam series and are extremely fragile. One, indeed, is divided near the middle by what has every appearance of being an old joint about half an inch wide, and the sides still parallel. Their nearest point of origin was several hundred feet distant. How such masses could have traveled even a short distance without falling to pieces, it is hard to see, unless they were firmly embedded in some matrix.

From a variety of circumstancs, I have the impression that the circs have been well cleaned of rocky débris, and that such material is now accumulating at their upper ends. The indications are strong that little save the finer débris now passes out. For the present, however, I should not care to lay much stress on these impressions.

While these deposits must be regarded as essentially nonglacial, there does not appear to be anything inconsistent with the assumption that occasionally during periods of exceptional activity, glaciers may have advanced on to them for short periods.

The field is very far from having been exhaustively worked, and until evidence is more nearly complete I prefer to reserve final expression of opinion.

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